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THREE EMPHASES IN TEACHING BIOLOGY--A STATISTICAL COMPARISON OF RESULTS.

BY- YAGER, ROBERT E. WICK, JOHN W.

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SEVERAL APPROACHES FOR TEACHING BIOLOGY IN EIGHTH GRADE CLASSES WERE COMPARED FOR EFFECTIVENESS IN IMPROVING STUDENT'S CRITICAL THINKING ABILITIES, UNDERSTANDING OF SCIENCE, AND KNOWLEDGE OF MAJOR CONCEPTS AND FACTS. STUDENTS WERE RANDOMLY ASSIGNED TO THREE CLASSES, EACH TAUGHT BY A TEAM OF THREE TEACHERS. CLASS A USED A TEXTBOOK LABORATORY APPROACH WITH EMPHASIS ON LEARNING BASIC CONCEPTS. CLASS B USED NUMEROUS REFERENCES AND EMPHASIZED THE VARIETY OF INTERPRETATIONS OF THEORY FORMATION STRESSED BY THE WRITERS. CLASS C USED A MULTIREFERENCE APPROACH AND EMPHASIZED THE MECHANICS OF THEORY FORMATION. THE STUDY WAS CONDUCTED DURING A 2-YEAR PERIOD. STUDENTS WERE TESTED FOR UNDERSTANDING OF SCIENCE, SKILLS IN CRITICAL THINKING, AND MASTERY OF CONTENT. ANALYSIS OF COVARIANCE WAS USED TO COMPARE PRE-TEST AND POST-TEST RESULTS. RESULTS OF THE TEST ON UNDERSTANDING SCIENCE INDICATED THAT CLASS C MADE SIGNIFICANTLY GREATER GAINS THAN EITHER CLASS A OR CLASS B. CLASS B MADE SIGNIFICANTLY GREATER GAINS THAN CLASS A. CLASSES B AND C MADE SIGNIFICANTLY GREATER GAINS THAN CLASS A ON THE TEST OF CRITICAL THINKING. NO CLASS WAS FOUND TO BE SUPERIOR ON THE TEST OF FACTUAL KNOWLEDGE. THIS ARTICLE IS PUBLISHED IN THE "JOURNAL OF RESEARCH IN SCIENCE TEACHING," VOLUME 4, ISSUE 1, 1966. (AG)

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How important are supplementary materials in instruction? This study suggests that such an approach contributes significantly to the development of critical thinking and science understanding.

Three Emphases in Teaching Biology—A Statistical Comparison of Results

ROBERT E. YAGER and JOHN W. WICK
University of Iowa, Iowa City, Iowa

Introduction

This is a report of a study conducted at the University of Iowa Laboratory School during the 1962 and 1963 academic years. The purpose of the study was to determine if it is possible to affect a student's understanding of science and his ability to do critical thinking by altering the emphases of the teacher in the classroom.

The course was taught at grade eight which is where the general education course in biology is taught in the school. The rationale for the junior high program has been described previously[1] and an outline of the course appeared in the secondary curriculum guide for 1962.[2] In general, the course can be described as one emphasizing the molecular level of biology and incorporating laboratory experiences to a high degree. Three teachers were used for each of three sections. The teachers worked closely together as a team and shifted from section to section periodically to teach various units of work. This was designed to reduce the teacher variable in the study. Each section of students spent the same amount of time with each unit, experienced the same laboratories, took the same examinations, and in general, were treated identically except for the variables reported in this study.

One section utilized only a textbook and the accompanying laboratory. This group is referred to as the TL group in the study. The textbook and the laboratory suggestions were the paperback editions of the second writing of the BSCS Blue Version material.[3] No other books or any other investigations were used with the group. The teachers avoided discussions of differences of opinion, interpretations, and reports of new findings. At times the material in the textbook touched upon these facets. However, class discussions avoided these areas. The emphasis was upon mastery of basic concepts as identified by the authors through an inquiry approach in the laboratory.

The second section utilized the same materials with the addition of all kinds of paperbacks, textbooks, various references, and excerpts from original works. Several special materials were paraphrased, duplicated, and used as handout material for the group. There was never any reference made to a textbook. Specific authors (or book in the case of the BSCS text) were identified when such information and authority was added to a discussion. Although the same unit sequence was used, a continuous effort was made to avoid identifying this sequence with a given textbook. All of the laboratory guides were prepared as single handout sheets, unrelated to a book. At times, student suggestions for additional procedures were added to the guides. Hence, there was an added involvement in planning the laboratory phase which was missing completely from the TL group. The teachers in the multireference-laboratory group (the MRL group) avoided reference to the controversy

which often occurred among the men responsible for the formation of fundamental theories. Attention was given only to the varying interpretations given by modern writers. No attention was given to the history involved with new discoveries and new ideas through the ages.

The third group in the study resembled the MRL group in the addition of constant attention and concern for the men involved with the development of the important ideas of the science. The teachers made a conscientious effort to show the mechanics of how the major ideas evolved. Constant reference was made to the major contributors with attention directed to their specific statements. Some time was spent discussing the culture of the time when the contributions were made. Again the same laboratories were utilized except that emphasis was placed on how this experiment would have been viewed by various people at various times in history. Then, emphasis was placed on how the major ideas were formed, changed, and finally perfected as we know them today. Some attention was given to how today's ideas will likely change in future years. The teachers in this group utilized the spirit of inquiry in the laboratory to emphasize it as the technique employed by the major contributors of the big ideas in biology. This group was termed the MRLI group (multireference-laboratory and idea group).

The three teachers had similar training and philosophy. They were each committed to doing the best job possible with each of the groups within the confines of the study as described. Each was interested in the results of the study and was involved with its planning as well as the implementation phases. However, none had a preconceived notion of the outcomes as reported here. The students were told that they were involved in a study. They realized that there were various emphases in the three sections. However, they were not aware of the precise problem under investigation, the method of attack, or the final outcomes. Involvement in such studies is a regular occurrence in the laboratory school. Hence the so-called "Hawthorne effect" is minimized.

The Measurement Instruments

Three aspects of the student's growth were under surveillance in this study. The three aspects were understanding of science, skills in critical thinking, and mastery of content. They were measured with the following instruments, respectively:

(*1*) *Test of Understanding Science* (TOUS);[4]

(*2*) *Watson-Glaser Critical Thinking Appraisal;*[5]

(*3*) *Nelson Biology Test.*[6]

Preconditions to the Results

The statistical handling of the resulting data was based on an analysis of covariance, closely following the exposition presented by Lindquist.[7] As mentioned in this exposition, compliance with certain conditions is required before the results can have any meaning. These conditions are as follows:

(*1*) Random selection of treatment groups must be assured. Since division of the seventy available students into the three classes was done on a random basis, chance variations in motivation or other elements affecting performance should have cancelled each other.

(*2*) The pretest scores must be unaffected by the measures, which was assured by administering the original test during the first week of class.

(*3*) The regression of the posttest scores on the pretest scores must be the same for all treatment populations. The results of this test are tabulated in Table I. It can be seen that in each case they are nonsignificant.

(*4*) It is necessary that the regression in each case be linear. This was examined using the F test ratio of mean square for departure from linearity over mean square within. In each case, the hypothesis that the pre- and post-tests were related in a linear manner could not be rejected.

TABLE I
Results for Tests of Homogeneity of Regression for the Three Instruments

Instrument	df	Mean square	F	$_{.01}F_{2,64}$
Tous				
Among group	2	14.6069	1.2454	≥4.98
Dev. from group	64	11.7291		
Watson-Glaser				
Among group	2	43.3137	2.6245	≥4.98
Dev. from n	64	16.5037		
Nelson				
Among group	2	1.0803	0.0952	≥4.98
Dev. from group	64	11.3527		

TABLE II
Analysis of Covariance Results for the Test of Understanding Science

Sources	df	$ss\ X$	$sp\ XY$	$ss\ Y$	$ss\ Y'$	df	$ms\ Y'$
Treatments (A)	2	21.4863	−92.4746	495.7441	694.3797	2	347.1899
Within (2)	67	4383.7852	4289.8184	4977.7422	779.8765	66	11.8163
Total	69	4405.2715	4197.3437	5473.4863	1474.2562	68	

(5) The distribution of adjusted scores for each treatment population must be normal. This is assumed to be the case.

(6) The distributions in each case must have the same variance. This was tested using Bartlett's test for homogeneity of variance, and the results in each case were nonsignificant.

TABLE III
Analysis of Covariance Results for the TOUS Test, Control, Criterion, and Adjusted Criterion Mean Values

	TL	MRL	MRLI
X means	28.8696	28.7917	27.6522
Y means	29.8261	33.0417	36.3913
Y' means	29.4085	32.7003	37.1650

The Results

Table II, concerning the understanding of science, indicates statistical results. Under the hypothesis that there is no difference in the student's performance on the TOUS test (that is, their understanding of science is unaffected by the method of presentation), the following result is obtained:

$$F(2,67) = 29.3823, \text{ where } F_{.95} = 3.14; \quad F_{.99} = 4.95$$

Thus the hypothesis that there is no difference can be rejected. Now the different pairs of groups can be examined more closely to see wherein this significant difference lies. The independent variable means X, criterion variable means Y, and adjusted criterion variable means Y' are listed in Table III.

The t test comparing the three possible pairings indicates (at the 0.01 level) that the MRLI method is significantly superior to the other two, and that the MRL is significantly better than the TL method. This, of course, is based on the premise that the TOUS really does measure ability to understand science.

Table IV indicates results concerning the ability to do critical thinking. Apparently the hypothesis that there is no difference in the student's performance on the Watson-Glaser Test of Critical Thinking must be rejected. Therefore, the groups must be examined more closely to determine where the difference exists. The independent variable means X, criterion variable means Y, and adjusted criterion variable means Y'

TABLE IV
Analysis of Covariance Results for the Watson-Glaser Test of Critical Thinking

Sources	df	$ss\ X$	$sp\ XY$	$ss\ Y$	$ss\ Y'$	df	$ms\ Y'$
Treatments (A)	2	205.7715	−167.5137	313.1621	802.7520	2	401.3760
Within (W)	67	7604.5293	7250.9141	8056.6094	1142.8673	66	17.3162
Total	69	7810.3008	7083.4004	8369.7715	1945.6193	68	

$F(2.66) = 23.1793$, where $F_{.95} = 3.14$; $F_{.99} = 4.95$

are given in Table V. The t test comparison for the three possible pairs indicate that both the MRL and MRLI are significantly superior to the TL method.

Table VI indicates results concerning the ability to retain factual knowledge in biology. With this data, $F(2,66) = 0.0015$, which is nonsignificant. Thus the hypothesis that there is no difference in the student's ability to learn and retain factual information because of the different methods of presentation cannot be rejected. There is no reason to pursue the data further because of this result.

TABLE V
Analysis of Covariance Results for the Watson-Glaser Test of Critical Thinking, Control, Criterion, and Adjusted Criterion Mean Values

	TL	MRL	MRLI
X means	45.3043	42.9167	41.0870
Y means	49.8696	55.0000	53.0000
Y' means	47.7677	55.1748	54.9194

Discussion

The role of the teacher in setting the tone of the classroom is an important factor in determining student outcomes. Although this study does not demonstrate that the teacher can affect the degree of mastery of concepts and facts of biology, this has been demonstrated in another earlier study when the teachers involved were more variable.[8] Because of significant differences in the results with the instruments used in this study, the question of other differences in student outcomes that may occur because of teacher emphases not measured with these instruments at once arises. There is also the question of whether these same results could occur when less skilled teachers were involved. Certainly the teachers involved here were all better than average. They averaged five years of experience and a content background consisting of fifty semester hours in biology at the graduate level. In addition, all had training in the history and philosophy of science.

In many recent reports of research in science teaching, the effect of the teacher upon learning is minimized. In fact, large numbers of teachers involved in a study are thought to be a control of the teacher variable. When specific emphases in the classroom can so alter experimental results, as reported here, this experimental design is certainly questioned. In fact, certain possible outcomes in particular studies may be completely hidden.

Conclusions

Certain student outcomes are demonstrated to be greater with certain teacher

TABLE VI
Analysis of Covariance Results for the Nelson Biology Test

Sources	df	$ss\ X$	$sp\ XY$	$ss\ Y$	$ss\ Y'$	df	$ms\ Y'$
Treatments (A)	2	4.1533	3.4902	2.9404	0.0336	2	0.0168
Within (W)	67	8056.1328	7409.7959	7544.0459	728.7319	66	11.0414
Total	69	8060.2861	7413.2861	7546.9863	728.7655	68	

emphases in teaching biology at the secondary level. Specific conclusions follow.

(*1*) Using a multireference approach in the biology classroom causes students to develop more skill in critical thinking than when a single textbook is used with the same laboratory investigations (as measured by the *Watson-Glaser Critical Thinking Appraisal*). This observation is significant at the 0.01 level of confidence.

(*2*) A multireference approach is equally superior to a single textbook-laboratory approach in causing students to understand science to a higher degree (as measured by the TOUS test). Again, this is significant at the 0.01 level of confidence.

(*3*) The multireference-laboratory approach with an added emphasis upon how the ideas were formed and upon the men primarily responsible for the ideas causes students to understand science (as measured by the TOUS) at an even higher level. This is significantly greater than the TL or the MRL method at the 0.01 level of confidence.

(*4*) There is no significant difference in the mastery of the major concepts and facts of biology (as measured by the Nelson Biology Test) by the students among the three emphases used by the teachers of the study.

(*5*) Teacher emphasis in the classroom is identified as an important factor in determining student outcomes in the teaching of general education biology. Various emphases cause varying degrees of understanding of the meaning of science and the development of skills of critical thinking by the students enrolled.

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